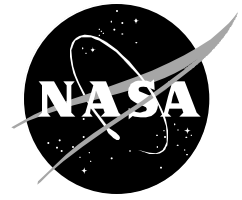


NASA Facts

National Aeronautics and
Space Administration



Office of Space Science

Washington, DC 20546

[HTTP://www.hq.nasa.gov/office/oss/](http://www.hq.nasa.gov/office/oss/)

October 1996

Our Sun: A Look Under the Hood

All solar energy is generated by hydrogen fusing into helium deep in the Sun's core. Understanding the Sun is a matter of tracing the energy transport through the Sun and out into space.

Inside the Sun

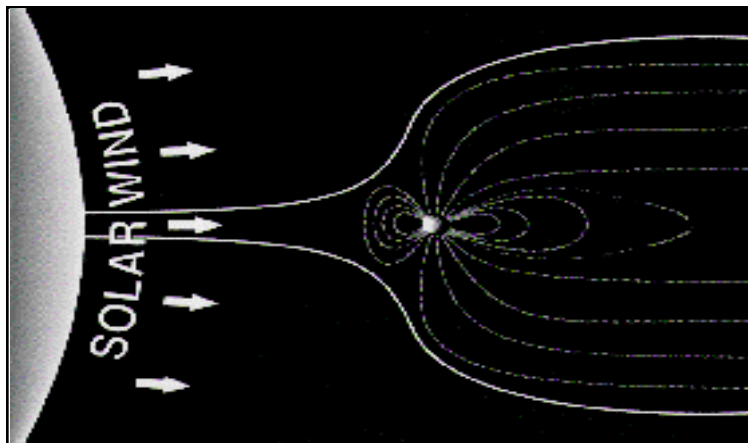
Most energy from fusion is released in the high energy form of radiation called *gamma rays*. Throughout most of the solar interior, this energy bounces around in the *radiative zone*, constantly being absorbed and re-emitted. As the energy works its way toward the surface, it slowly degrades to lower energy radiation. About three-quarters of the way out, this radiation heats the cooler outer layers of the Sun, creating convection.

In this *convection zone*, some of the energy is transported outward by the rising of warm gas and the sinking of cool gas. The entire process is long; the energy we receive from the Sun today was produced by fusion reactions that took place thousands, or hundreds of thousands, of years ago.

The Surface of the Sun

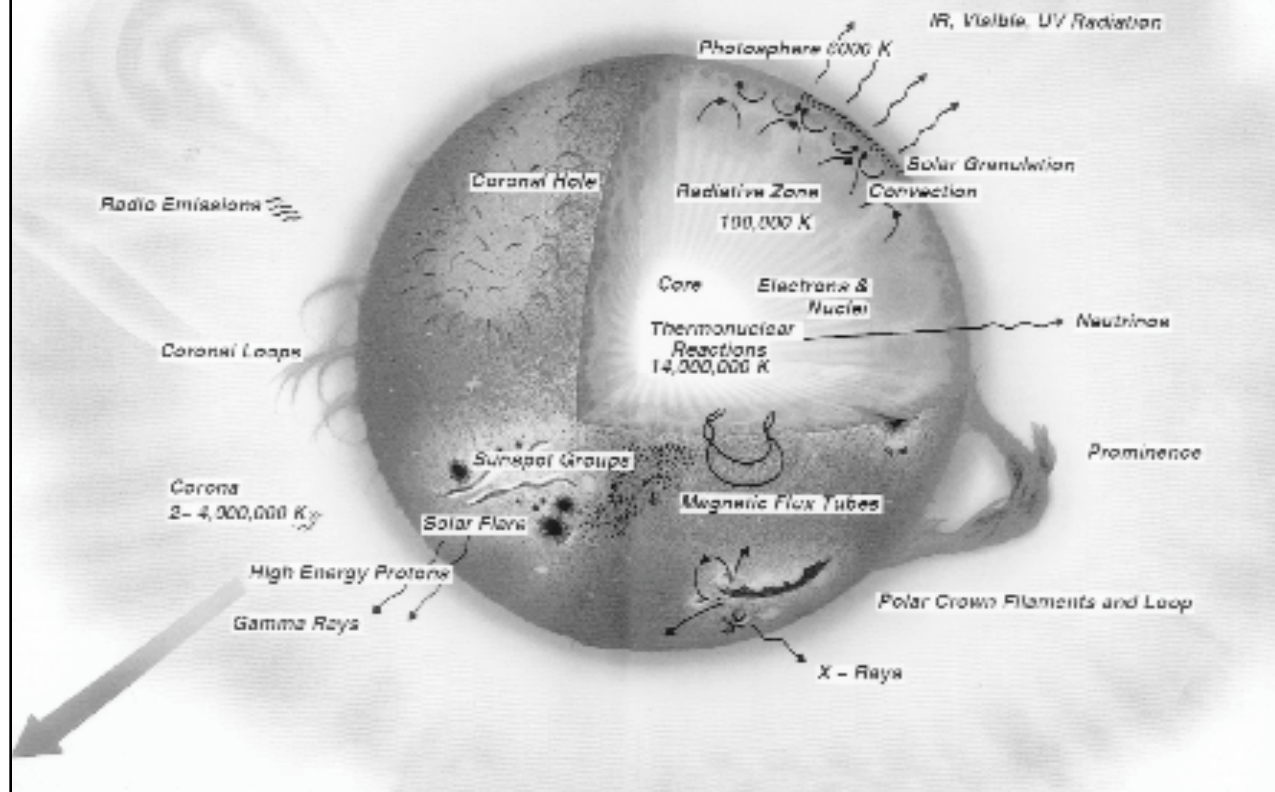
The Sun is a gas ball throughout; held together by gravity. An object falling into the Sun would never encounter a definite "surface" like on Earth. The visible surface of the Sun, or photosphere, is simply the layer of gas from which most of the energy escapes as light into space. Traveling at 300,000

kilometers per second (186,000 miles per second — the speed of light), light from the photosphere takes about 8 minutes to reach the Earth. The photosphere looks substantial but is actually far less dense than the air on Earth (about 500 times less than air at sea level). By earthly standards it is very hot — about 5,000-6,000 degrees — but it is the coolest layer of the Sun. Detailed images of the photosphere reveal a complex blotchy appearance called *granulation*. Each "granule" represents the top of a convection cell, bright where hot gas is welling up and dark where cooler gas is sinking down. The most notable structures are *sunspots*, regions of gas that are cooler than their surroundings and are shaped by strong magnetic fields.



Artist concept of the solar wind interacting with the Earth's magnetic field. NASA is working with other space agencies to better understand the Sun's impact on the Earth.

Inside and Outside the Sun



Artist's concept of the Sun illustrating its many layers and features, including the core, radiative and convective regions, the photosphere, chromosphere, prominences, sunspots and the solar wind.

The Chromosphere and Corona

The temperature and density of the Sun decrease from extremely high levels in the Sun's core to much lower levels in the relatively cool photosphere. Above the photosphere, densities continue to decrease in the *chromosphere* and *corona*. Surprisingly, however, temperatures actually rise in these regions. Just what makes these upper layers hotter is one of the great mysteries in astrophysics. The chromosphere, with temperatures of up to tens of thousands of degrees, shines predominately in deep red light. The corona, at a million degrees or more, shines predominately in x-rays. From the ground, the corona can only be seen during a total eclipse, when it appears as a shimmering halo around the eclipsed solar disk.

Unlike the relatively steady photosphere, the chromosphere and corona are highly variable. Immense bursts of light called *solar flares* occur in the chromosphere. Flares are caused by the sudden release of energy stored in the complex,

twisted magnetic fields above sunspots. Giant *prominences*, huge streams or loops of gas, rise through the chromosphere and corona. Also shaped by magnetic fields, prominences may survive up to a few weeks.

The Solar Wind

Material from the solar corona expands outward in a flow of atomic particles called the *solar wind*. Though its density is so low we would consider it a good laboratory vacuum here on Earth, the solar wind has real effects on the worlds in our solar system and beyond. The solar wind sweeps outward from the Sun at speeds from 350 to 700 kilometers per second (217 to 434 miles per second). Because the Sun also rotates, approximately once every 27 days, the solar wind forms a complex spiral pattern in all directions, distorted by the eruptions of flares and other energetic solar events. Because the solar wind extends throughout the solar system, the Earth effectively lives in the extended outer atmosphere of the Sun.

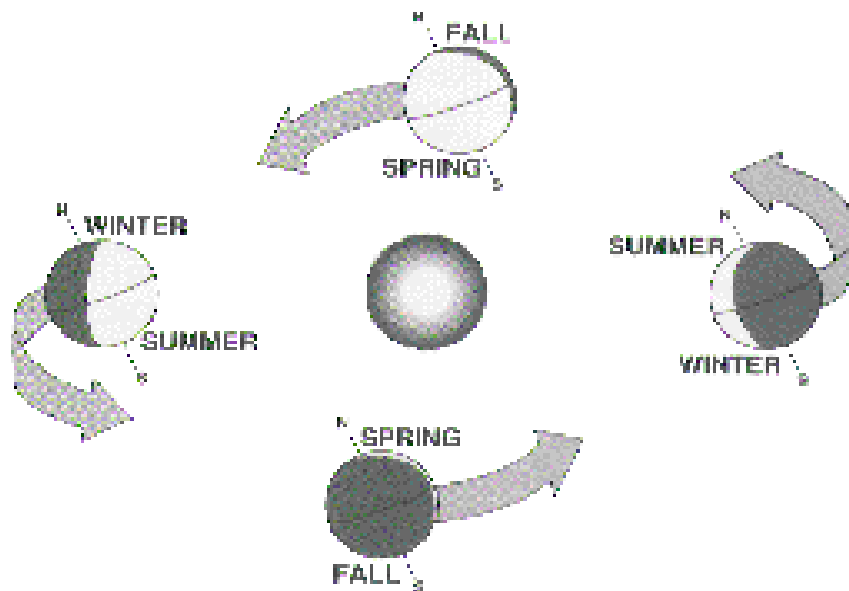
Living with a Star: Our Sun

The Earth receives only about one-billionth of the energy given off by the Sun, but this is enough to sustain the great diversity of life on our planet. The circulation of our atmosphere, the currents of our oceans, the photosynthesis at the base of our food chain — all are driven by energy from the Sun. Even the energy used by humans, with the exception of nuclear and geothermal energy, can be traced back to the Sun. The flow of rivers for hydroelectric power, for example, is driven by the solar heat that causes evaporation and rainfall. Fossil fuels, like coal, oil and natural gas, are the remains of organic life that depended on photosynthesis.

Solar Activity

The total energy output of the Sun is nearly constant over time. This is fortunate since any significant variability would have devastating consequences for

the Earth. A few aspects of the Sun vary, and we call that solar activity. The most obvious example of solar activity is the sunspot cycle. The total number of sunspots on the Sun varies in an approximately 11-year cycle. Because sunspots are regions of intense magnetic fields, many other solar phenomena are connected with them. Solar Flares, for example, occur near sunspots and are more common during solar maximum (that part of the solar cycle where the number of sunspots is high). Sunspots have been observed regularly since Galileo first noticed them through his telescope in 1610. Ancient Chinese records contain many sightings of sunspots. Individual sunspots last no more than a few weeks, but new ones are constantly forming as old ones disappear.



The most basic connection between the Sun and the weather on Earth is found in the pattern of the seasons. Seasons occur because of variations in the amount of sunlight received in different regions of the globe at different times of year. The direct cause of seasons is the Earth's obliquity — the Earth rotates on an axis tilted 23.5 degrees from the axis of its orbit around the Sun. As the Earth orbits, its axis remains pointed in the same direction in space so that the northern and southern hemispheres alternatively face toward the Sun. Thus, seasons are opposite in the two hemispheres: winter occurs in the northern hemisphere when summer occurs in the southern hemisphere, and vice versa. In this way, all life on Earth, especially planting seasons, are directly affected by Sun-Earth interactions.



Soft x-ray image of the Sun (taken by Japan/US telescope on the Yohkoh spacecraft) showing several active regions and its extended corona.

Solar Storms

Solar storms are dramatic changes in our solar system that are the result of solar activity. The ground does not shake and the sky does not turn black when a solar storm strikes the Earth. In fact, you could be outside during such a storm and might never know it was happening. While a solar storm is invisible but for the ghostly auroras it creates, the danger it poses is very real. Huge power blackouts, blown-up power transformers, melted conductors, and failures in sensitive communications satellites are just a few of a storm's possible effects. Because solar storms attack the very foundation of our high-tech society, scientists are excited to find that satellite data will help them predict solar storms and mitigate their impact on Earth.

Researchers are making many discoveries using the Japan/US soft x-ray telescope on the Yohkoh spacecraft. With Yohkoh, which means "sunbeam" in Japanese, we have been able to see a sudden darkening of the Sun's usually bright x-ray corona just before a huge explosion sends billions of tons of charged particles hurtling through our solar system. Since it takes two or three days for these particles to reach

Earth, being able to spot the darkening means engineers would have enough time to protect the North American power grid and any threatened satellites.

Yohkoh and several other spacecraft being readied for launch will monitor the Sun closely for advanced warning of solar storms. We should get at least an hour's warning and possibly up to a few days. This will be enough for engineers to prevent blackouts like the one a few years ago in Quebec that was caused by a solar storm and that almost spread to the mid-Atlantic states in the US. North America is most affected by solar storms because we are closest to the Earth's magnetic north pole and our power grid extends into high latitudes.

Like hurricanes, earthquakes and other natural disasters, we probably will never be able to totally prevent damage from solar storms. But the advanced warning made possible by satellites like Yohkoh will help us keep the damage to a minimum, hopefully avoiding millions of dollars in damaged power and communications equipment, and untold cost and inconvenience to power customers.